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THE REVIEW

DEVOTED TO THE INTERESTS OF THE AMERICAN SOCIETY FOR METALS

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Strip Formed Directly From Molten Metal

Hazelett Process Is One of the Most Important and Interesting Metallurgical Developments in Recent Years

By Emerson S. Norris

Baltimore Chapter—One of the most important and interesting developments in recent years in the metallurgical industry, the Hazelett process for the production of strip directly from molten metal, was the subject of the meeting on May 10.

Matthew Schon, development engineer and manager of Metals Division, The Crown Cork & Seal Co., Baltimore, delivered the address, illustrating it with motion pictures and slides.

After considerable work most of the difficulties have been overcome and the Crown Cork & Seal Co. has placed the Hazelett process on a production basis in making aluminum.

In brief, the Hazelett process is as follows: Aluminum (or any other metal) is melted in an electric furnace carefully to make an extremely clean metal. The metal is poured into a launder and flows through nozzles made of special refractory material into the vee formed between two horizontal rolls. A small reservoir of metal is maintained at this point.

Metal Solidifies in Rolls

As the metal passes through the nip of the rolls it solidifies and emerges in the form of a sheet which is coiled under tension on a reel. It is now in condition to be processed further by regular rolling methods.

As any metallurgist can readily see, there are a number of serious problems to overcome.

In regular rolling practice considerable metal is cropped off the billets to eliminate various defects. The Hazelett process, of course, does not have such procedure available and must start with exceptionally clean metal to avoid poor quality sheet.

In pouring a heat very careful control on the rate of metal flow must be maintained. Special refractories were developed for nozzles to regulate the flow. The nozzles must operate submerged in the reservoir between the rolls to prevent splashing.

The function of the rolls is two-fold. They serve to remove sufficient heat from the metal to solidify it and to

(Continued on page 2)

Hardy Speaks on Powder Metallurgy at Detroit

By Howard E. DeHaven

Detroit Chapter—"Powder Metallurgy" was the subject of a talk, well illustrated by slides and accompanied by exhibits of a number of parts made from metal powders, at the concluding meeting of the season held May 10.

Charles Hardy, pioneer in powder metallurgy, was the speaker. Since his paper will appear in full in an early issue of *Metal Progress*, it will not be reported in THE REVIEW at this time.

At the conclusion of the talk, many pertinent items were discussed by several men from the district who are using metal powders in production.

The Auditorium, Atlantic City, at Night

Floodlights and the Atlantic Ocean Combine to Produce This Striking Night View of the Building Which Will House the National Metal Exposition in Atlantic City Next October.

Compliments

To **Gilbert E. Doan**, A.S.M., who has been advanced to the position of professor of metallurgy, Lehigh University, Bethlehem, Pa.

To **W. H. Swanger**, chairman of the Washington Chapter A.S.M., and **George F. Wohlgemuth**, both associated with the Bureau of Standards, on having been awarded the Dudley Medal of the American Society for Testing Materials.

To **F. O. Hoagland**, master mechanic, Pratt & Whitney Division, Niles Bement-Pond Co., Hartford Chapter, on having been nominated to serve for one year as vice-president of the American Society of Mechanical Engineers.

To **C. R. Culling**, vice-president, Carondelet Foundry Co., member of the Executive Committee of the St. Louis Chapter, on his nomination as a director of the Gray Iron Founders' Society.

To **Axel Weydell**, many years treasurer of the Indianapolis Chapter, who celebrated his 70th birthday on June 8.

To **Zay Jeffries**, past president A.S.M., who received the honorary degree of Doctor of Engineering from Case School of Applied Science at the annual commencement on June 7.

Assistant Secretary Named

Because of the increasing amount of detail work occasioned by the growing size of the Chicago Chapter, the Executive Committee has created the office of assistant secretary.

E. A. Terwell of the Driver-Harris Co. was elected to this newly created position for the year 1937-38.

Panel Discussion on Tool Hardening Held

Three Dayton Speakers Discuss the Atmosphere, the Steel and the Results

By Richard R. Kennedy

Dayton Chapter closed a successful season on May 12 with the introduction of the new officers, new Chairman R. W. Weber taking charge of the meeting.

The first speaker was none other than National Secretary "Bill" Eisenman, who spoke on metallurgy, farming, the state of the A.S.M., and many other topics in his characteristic manner.

The technical portion of the program consisted of a panel discussion on "Controlled Tool Hardening."

F. M. Reiter of Dayton Power & Light Co. (who had just been re-elected secretary of the Chapter for the 11th year) spoke first on "The Atmosphere." He discussed the chemical reactions which take place in combustion and the nature of the reactions between the steel and the gases present in the furnace.

L. H. Grenell of Frigidaire Corp. spoke on "The Steel," stressing the importance of adjusting the atmosphere to the type of steel and the object of the heat treatment.

E. C. Adkins then discussed "The Results," basing his remarks on his wide experience in the heat treatment of all types of steel.

He described various types of furnaces, such as electric furnaces with an uncontrolled oxidizing atmosphere, gas furnaces in which the atmosphere is controlled to some extent by using a rich mixture, and some of the newer furnaces in which the atmosphere consists of burned gases or raw natural gas.

Even after adjournment of the meeting, a spirited discussion was continued over an excellent lunch served by the Chapter.

Only 31 Spaces Are Left Open At Metal Expo

Show Is Filled so Regularly This Is no Longer News Says Managing Director Eisenman

"The Metal Show has been filled to capacity so regularly in the last few years that it is no longer news when 91% of the exhibit space at the 19th National Metal Exposition, to be held Oct. 18 to 22 in Atlantic City, has already been contracted for by 189 industrial companies," said W. H. Eisenman, A.S.M. secretary and managing director of the Show.

"It is news, however, when so much of the exhibit space is contracted for five months in advance of the opening date. And it is news too when this is the result of an announcement only to a select group of previous exhibitors.

"In other words," Mr. Eisenman concluded, "with only 31 exhibit spaces remaining, we have yet to contact formally the general list of hundreds of industrial prospects who should be represented."

The Atlantic City Auditorium provides an ideal site for this year's Metal Show. It is a huge building with 154,348 sq. ft. of space on one floor, unencumbered by pillars or posts to interfere with a broad view of all exhibits.

The National Metal Congress, held in conjunction with the Metal Show, convenes on the second floor of the Auditorium. Five international societies in addition to the American Society for Metals will cooperate in this event, namely, the Iron and Steel and Institute of Metals divisions of the American Institute of Mining and Metallurgical Engineers, the American Welding Society, American Society of Mechanical Engineers and the Wire Association.

Pitfalls of Deep Drawing And Ways to Avoid Them Are Pointed Out by Leiter

Southern Tier Chapter—L. C. Conradi, technical research director of International Business Machines Corp., spoke a few words of welcome to the members and guests assembled for a meeting at the I.B.M. Country Club House on May 17.

Dr. Garland B. Briggs, dean of I.B.M.'s Educational Department, gave a short talk expressing his interest in the work which the A.S.M. is doing.

Following a report of the annual election of officers, retiring Chairman W. R. Stamp introduced Dr. Ralph Leiter of the Edward G. Budd Mfg. Co., Philadelphia, who presented an interesting paper on the deep drawing of steel.

Dr. Leiter pointed out a good many of the pitfalls which beset the manufacturer of deep drawn articles and indicated the way to avoid these troubles.

He also told of some of the work which his company is doing in the manufacture of parts from stainless steel with direct reference to the fabrication of the new streamlined trains. The Budd Co. is a pioneer in this field, and the discussion of this phase of their work was extremely interesting to all.

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RAY T. BAYLESS.....*Editor*
M. R. HYSLOP.....*Managing Editor*

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Gleanings . . .

. . . from the chapters

Comment From India . . .

A new high in reader interest or some such thing was chalked up by THE REVIEW when an air mail letter came all the way from Jamshedpur, India, commenting on a statement in the "Do You Know" column of the March issue.

The letter was written on May 25 by R. F. Biddle of the Tata Iron & Steel Co., Ltd., and reached our office on June 9. Mr. Biddle's comment follows:

"Exception is taken to the statement that 'most of the world's supply of titanium comes from sands on river banks in the interior of Brazil.' It is claimed by our Prospecting Department that most of the world's supply of titanium comes from the beach sands of Travancore, India. India has been the world's largest producer of Ilmenite (titanium ore) since 1927."

We stand corrected!

Ten Years Old . . .

The Dayton Chapter recently celebrated its tenth anniversary. Past chairmen were honored at a special dinner, at which first chairman George J. Oswald presented a tribute to the generous efforts of Herbert H. Skinner that culminated in 1927 in the founding of the Chapter.

Standby's . . .

Charles Wesley Jr. and Robert B. Pottinger have been members of the Milwaukee Chapter ever since its installation in 1919, and rarely miss a meeting.

No Slights Intended . . .

Reports of the newly elected chapter officers are coming in to the National Office in batches. They will not, however, be published until the August issue when the list will be entirely complete.

We wish we could publish these lists with the prominence that the importance of the elections deserves, but lack of space will probably force us again to print the names in eye-straining six-point type.

At any rate, congratulations, all!

Kloster Completes Warehouse

Kloster Steel Corp., Chicago, has just completed the erection of a large and modern tool steel warehouse which will carry one of the largest tool steel stocks in the middle west.

Kloster markets tool and alloy steels under the trade name "Pure-Ore."

Earliest Forgings Date Back To 3000 B.C. Says De Ridder

Traces History and Tells of Modern Improvements in Forging Practice; Plant Visit and Movie Also on Program

By Louie W. Mosley

Los Angeles Chapter—A full program beginning with a visit to the forging plant of General Metals Corp., featured the May meeting. For two hours in the late afternoon the General Metals forging crew displayed their best hammer work, extrusion forging, and die forging for the entertainment of over 100 A.S.M. members.

The plant visitation was followed by a banquet after which Chapter officers for the next fiscal year were elected.

The program of the evening consisted of a talk on forgings presented by W. A. De Ridder, vice-president of the General Metals Corp., and a moving picture furnished by the Transue & Williams Steel Forging Corp. through the courtesy of R. W. Thompson, sales engineer.

Mr. De Ridder stated that forgings date back to 3000 B. C., having been made in Egypt, China, and in some of the old civilizations of Asia Minor. In the Middle Ages the craftsmanship of the blacksmith was regarded with much respect, and elevated him to a place of importance.

First Steam Hammer in 1838

The first single-acting steam hammer was invented in 1838, and the first double-acting steam hammer was built in 1888. In 1868 the first true drop forging was made.

The automobile has been the largest factor contributing to the growth of the forging industry. Requirements of lightness and strength in this field have practically demanded forgings; this is particularly true in the case of aeronautical engines. Forgings have been used for all types of industrial applications, but about 80% of the total has gone into automobiles.

Much improvement has been made in the methods and materials for drop-forging dies. Forged blocks of Ni-Cr-Mo steel are used for these impression blocks. When cast, these blocks can be made with a part of the impression cast into them, thereby decreasing the amount of work in finishing.

Hard Facing for Dies

Inserted blocks help to prolong the life of drop-forging dies, and hard-facing is often applied to the cutting edges to withstand extremely severe service.

Correct design is important also in parting the dies so that half of the total mass is made in each half of the complete die. Greater production per hammer is obtained by making multiple dies so that two or more of the same part is made at one stroke.

Greater complexity in designs of drop forgings has necessitated the inclusion of more and more equipment and machines for making these dies in the modern forging plant.

Mr. De Ridder stated that there is considerable argument about commercial and close tolerances; even when the tolerances are very close at first, disintegration of the metal in the dies under the high temperatures encountered soon sets in and changes their dimensions.

Testing of forged parts is very thorough, beginning with the metal from which the forged product is to be made. De-scaling of finished forgings is accomplished by one of several different methods, and inspection of the final product is accomplished by subjecting it to several severe tests.

The motion picture which followed showed forging operations in the large plant of the Transue & Williams Steel Forging Corp., including shots of their great 16,000-lb. hammer in action, and many interesting views of die-forging and other modern practices.

No July or Sept. Issue

Summertime means vacation time for THE REVIEW *as well as for most of its readers and contributors. There will be no issue during July and September.*

The August issue will carry the names of new officers of the chapters and a list of preprints of convention papers. The October issue will be devoted to the National Metal Congress and Exposition and will carry a complete program of events.

Gage Manufacturers Pool Their Designs

Cooperate in Order to Standardize Gage Types, Johnson Tells Golden Gate

By C. W. Horack

Golden Gate Chapter—Gages may sound like a simple enough subject but the large number of men, some of whom made long trips in order to be present at the meeting on April 19, indicated more than passing interest in the subject.

Clinton V. Johnson, Pratt & Whitney Division, Niles-Bement-Pond Co., was the speaker. Among his first remarks was a greeting from Mr. d'Arcambal who addressed the Chapter last fall.

Mr. Johnson confined his remarks to the general aspects of the application and uses of gages in industry. For the economical use of gages he stressed the importance of properly planning the inspection program with a view to inspecting only where necessary and thus keeping costs at a minimum.

In discussing the standardization of many types of gages, Mr. Johnson mentioned the cooperation of various gage manufacturers in pooling some of their designs for the common good of the industry. This has resulted in a great reduction in the variety of certain types of gages, such as plain plug and ring and thread plug gages.

It was also pointed out that considerable work is being done to eliminate the human element in gaging, such as through the application of automatic indicating gaging devices and the use of predetermined pressures when making measurements. Examples are the gaging of piston pins by the electric indicating gage and the measuring of pitch diameters of large and small screw threads under definite pressures.

The importance of gaging under constant temperature conditions was mentioned, as was also the importance of determining the proper tolerances on parts to be gaged by any kind of limit gages.

At the conclusion of the talk the members spent considerable time inspecting a large variety of gages which had been placed on exhibit by one of the local machine tool and gage distributors.

Jelliff Purchases Wire Plant

The C. O. Jelliff Mfg. Corp. of Southport, Conn., has recently purchased the Resistance Wire Division of George W. Prentiss and Co. of Holyoke, Mass.

DO YOU KNOW

THAT

- THAT . . . wire for milady's bobby pins comes in two shapes, eight thicknesses, seven widths and four finishes? And all the time we thought one bobby pin looked just like another.
- THAT . . . steel production the week of April 20 was the biggest in history? It totaled 1,196,000 tons.
- THAT . . . it would take a strip of tin 8 in. wide and long enough to go approximately nine times around the world, to make the 3,500,000,000 cans in which dog food was packed last year? That's really putting on the dog!
- THAT . . . a phosphor bronze disk saw was used to cut the famous Jonker diamond? Operating at 5000 revolutions per min., the saw required several months to complete the job.
- THAT . . . a modern locomotive contains more than 1½ miles of tubular piping?
- THAT . . . Paul Revere of "midnight ride" fame was the first manufacturer of copper sheets and bolts in the country? He was also an excellent silversmith and a noted cartoonist, executing his drawing on copper plates.
- THAT . . . the use of alloy steel, over the past 20 years, has cut in half the weight of the average car?
- THAT . . . only 31 exhibit spaces remain at the Auditorium in Atlantic City where the 19th National Metal Exposition will be held Oct. 18 to 22?

Hazelett Process Produces Strip From Molten Metal

(Continued from page 1)

roll the solidified metal into a strip. It is necessary to use high rolling pressures to remove the structure of metal caused by the chilling effects of the roll.

Sheet with a gage of 0.120 in. is about the maximum possible at the present time which can pass metallurgical inspection or be cold rolled immediately.

After passing the nip the rolls must be externally cooled with water sprays, the water must then be removed by compressed air and the surface of the roll finally wiped clean.

Serious difficulty arises due to heat checking of the rolls and rolls with sufficient resistance are hard to find. Rolls on aluminum will hold up to the extent of about 65 tons.

There are some limitations to the process. Aluminum cannot be poured at a rate greater than 44 lb. per min. Steel pours at 281 lb. per min.

Heats are limited to three tons, because the molten metal cannot, of course, be held too long in the furnace.

Aluminum can be rolled into strip by this process for about $.02 per pound, which is considerably better than the cost of rolling by conventional methods.

This, however, would be a high cost for steel, which is therefore not likely to compete in this field.

York Annual Meeting Held

By D. E. Flinchbaugh

York Chapter's annual meeting was held at the Grand View Country Club of York on June 5.

At the afternoon session the members enjoyed golf, badminton and mushball, interrupted only by occasional refreshments.

Luncheon was served at six o'clock, and was followed by a business meeting, when the Chapter officers were installed for the year 1937-38.

HERE AND THERE WITH A.S.M. MEMBERS

NOMINATED for president of the American Society for Testing Materials is ALBERT EASTON WHITE, professor of metallurgical engineering, and director of the Department of Engineering Research, University of Michigan.

A. E. White

Professor White, who was the first president of the American Society for Metals back in 1920, has taught at University of Michigan since 1911 and claims authorship of somewhere between 40 and 50 technical papers.

* * *

TWO other members of the A.S.M. were nominated to the Executive Committee of the A.S.T.M. They are RICHARD LAURENCE TEMPLIN, chief engineer of tests, Aluminum Co. of America, New Kensington, Pa., and H. C. MOUGEY, assistant technical director and chief chemist, Research Laboratories, General Motors Corp., Detroit.

R. L. Templin

Mr. Templin was the A.S.M. representative at the Congress of the International Association for Testing Materials in London Last April.

A. W. SIKES, past chairman of the Chicago Chapter, has recently been transferred from Washington, D. C., to the Chicago office of the Public Works Administration, Engineering Division.

Mr. Sikes, who holds a commission as Captain, Chemical Warfare Service Reserves, was graduated May 1 from the three months' Line and Staff Officers Course, Chemical Warfare Service School of the United States Army at Edgewood Arsenal, Maryland.

* * *

RESIGNING after five years as district sales manager in the Chicago District for The Midvale Co., J. R. HECKMAN has now become district manager of the General Alloys Co. in the same territory.

J. C. GLASS, who has been associated with The Midvale Co. for the past 17 years in the Cleveland district, has succeeded Mr. Heckman.

ASSOCIATED with Electro Metallurgical Sales Corp. since his graduation from Yale University in 1933, JOHN WILBUR has now been appointed to the Cleveland office.

He was first associated with the Niagara Falls Works and for the past year and a half has been in the New York office.

* * *

CHARLES L. SAUNDERS, formerly regional sales manager for Minneapolis-Honeywell Regulator Co. at Chicago, has been promoted as resident vice-president in charge of the midwest region.

* * *

J. B. SHELBY and JOSEPH SAMMON are co-managers of the Foundry Division of the Driver-Harris Co. Mr. Shelby has recently been advanced from the position of sales engineer in charge of the northern New York State and eastern Pennsylvania territory.

A. H. ALLEN, formerly associate editor of *Steel* and member of the Executive Committee of the Cleveland Chapter, has been transferred to the new Detroit office of the magazine as Detroit editor.

* * *

GEORGE H. PORTER, president of the George H. Porter Steel Treating Co., Cleveland, died Tuesday, May 11.

Safety Factors Based on Elastic Limit Predicted in Talk on Low Alloy Steels

By J. W. McBean

Ontario Chapter—The address at the May meeting was given by A. E. Gibson, president of the Wellman Engineering Co., Cleveland. It covered the arc welding, heat treatment and properties of low alloy, high strength steels.

A great many low alloy steels are now used in welded engineering structures with a carbon content of 0.2 or 0.1% and one, two, three or four of the alloying elements silicon, manganese, chromium, nickel, vanadium, molybdenum and copper. The tensile strength may be as high as 90,000 psi. and the yield point 60,000 psi.

Even higher figures are possible but impact resistance and other properties such as ductility and fatigue resistance are often more important than ultimate strength.

Higher Carbon Used With Precaution

Suitable heat treatment of some of these steels gives a high elastic limit, which may also be of more importance than the ultimate strength. The future trend will probably be to base safety factors on the elastic limit.

Where resistance to abrasion is important, higher carbon (0.30 to 0.40%) may be used with manganese from 1.25 to 2%, but if no precautions are taken, such material may crack at the weld or in the parent metal. Cracking can be avoided by preheating from 300 or 600° F.

With the higher carbons stresses can be relieved after welding by a modified normalizing process. The steel is heated to about 1650° F., which is high enough to form a solid solution of all the constituents, but not high enough to coarsen the grain, and the grain is set by raising the pot covers until the temperature falls to about 1000° F. The covers are then replaced and the pots allowed to cool slowly relieving the stresses.

For high strength in conjunction with corrosion resistance it is found that copper and phosphorus are very useful, the latter up to 0.12 or 0.14%. This is one of the interesting recent developments which would have been considered quite unorthodox a few years ago.

In some of the American steels the copper content is from 0.5 to 1.5%, and often nickel or some other element is used. These steels are very promising, producing high elastic limits combined with low air hardening and good resistance to fatigue and impact.

Steel with 2% nickel and about 0.08% carbon produces a yield strength of about 35,000 psi. Adding 1% copper to this same analysis increases the yield to approximately 55,000 psi. (an increase of over 57%).

An interesting phenomenon of the nickel-copper steel is its property of precipitation hardening in which the yield and ultimate strength may be greatly increased by heating to about 900° F. and air cooling. This treatment dangerously reduces the impact strength and is not recommended unless the material is first normalized before precipitation hardening.

Alloy Electrodes Used

The use of alloyed electrodes, the alloys being present in the steel or in the coating, makes possible deposited metal of superior physical properties. Molybdenum is the alloy most commonly used.

In making a weld in low alloy steels, a considerable quantity of the parent metal is fused, and hence alloys the filler metal. The amount of plate alloy found in deposited metal as a result of the fusion of the parent steel may be as high as 50% of that found in the steel. Naturally these alloys improve the properties of the weld.

Difficulties met with air hardening following torch cutting have been eliminated by using a special torch with two tips, a cutting tip followed by a heating tip on the same torch, which anneals the metal. Local hardening can be secured by using a water jet following the torch at the points to be hardened.

The saving in weight which can be made by the use of high strength steel and welded fabrication was illustrated by a dragline bucket in which weight was reduced from 4400 lb. to 3300 lb., making available 1100 lb. more pay load.

The type of weld, size of rod, kind of rod, and heat treatment should be specified by the designer and this is facilitated by the use of uniform symbols which will shortly be broadcast by the American Welding Society.

Research Classified As Fundamental or Engineering Type

By Merrill A. Scheil

Milwaukee Chapter — The May meeting was dedicated to the sustaining members of the Chapter. Representatives of 23 firms were treated to a technical address by L. A. Hawkins, General Electric Co., and to a buffet supper with plenty of the good old "amber fluid" for which Milwaukee is famous.

Mr. Hawkins discussed the difference between fundamental research and engineering research.

Intensive or engineering research brings new products and engages the energies of most laboratories. This type of research is the best type of insurance.

To illustrate the importance of fundamental research to industry, Mr. Hawkins used as an example the work of the General Electric Laboratories. He pointed to three important discoveries in the field of electric light bulbs that were made from purely scientific investigations which later led to commercial applications.

Another example of pure research was Langmuir's investigations of the so-called Edison effect, which resulted in the discovery of the space charge effect and made possible the high power, high vacuum tube.

Further interesting researches were cited which led to the development of the atomic hydrogen welding torch.

In tracing these original investigations through to some commercial application the speaker stressed the point that scientific facts are the raw materials of engineering and that metallurgical progress has been slow because it is largely empirical. An example of this is the work that has been done in the past seven years on creep testing which has resulted in specifications for steel twice as strong as before.

In the metallurgical field there is great need of fundamental research, limited only by the availability or capability of men for this kind of research. The man must be free to pioneer and to use his own methods and ideas.

Mr. Hawkins believes that the answer to many of our metal problems lies in the knowledge of "atomic physics" which leads to the fundamentals of metals.

Chicago Members Inspect Notre Dame Engineering Labs

Kinzel Addresses Joint Meeting on Alloy Additions to Steel

By W. E. Remmers

A large delegation of Chicago members journeyed to the University of Notre Dame on Saturday, April 24, to be guests of the Notre Dame Chapter.

After an inspection of the Engineering Laboratories a delightful dinner was served in the University dining hall, where the Reverend Father J. F. O'Hara, president of the University, greeted the visitors.

After several other short talks, the meeting adjourned to the Engineering Auditorium for an address by A. B. Kinzel, chief metallurgist of the Union Carbide and Carbon Research Laboratories, Inc., on "Some Specific Effects of Deoxidizing and Alloying Additions to Steel."

Dr. Kinzel divided the alloys into three groups—namely, carbide-forming elements, those which are primarily deoxidizers or degasifiers, and the solid solution-forming alloys.

Reasons for Alloys Given

In a discussion of the essentials for a balanced analysis in alloy steel, Dr. Kinzel mentioned the reasons for normally using more than one alloy in addition to carbon to obtain the desired properties. A broad range of alloy steels, from the low alloy to the relatively high chromium and chromium-nickel stainless alloys, was considered in detail, and the addition of the alloys justified in each case.

The effect of columbium as a carbide-former in the 4 to 6% chromium steels and in the stainless steels was discussed and the role of nitrogen in high chromium steels was traced from its original development to the present-day use.

In conclusion, a hypothesis was suggested relating the various embrittlement and localized corrosion phenomena to a common cause.

Although heavy rains during the day prevented many of the visitors from accepting the kind invitation of the University to play golf on the University course, this joint meeting of the Chicago and Notre Dame Chapters was an outstanding success, due, in a large measure, to the active efforts of E. G. Mahin of the Metallurgical Department of the University and his student committee.

Research Positions Open

Four appointments as research associate will be available at Battelle Memorial Institute, Columbus, Ohio, for the year 1937-38.

Appointments are for September to August inclusive and are open to graduates of any accredited university or college. The salary will be from $1200 to $1800 a year, depending upon the training and experience of the individual.

Application forms and further information may be secured by writing the Director, Battelle Memorial Institute, Columbus, Ohio.

Free Literature — Mail Coupon Below

Induction Furnaces
A publication of Ajax Electrothermic Corp. tells of the development, operating principles, applications, and advantages of commercial Ajax-Northrup coreless induction furnaces energized by motor generator sets. Also information regarding standard sizes of motor generator sets and furnaces. Bulletin Jr-41.

Coated Electrodes
General information on welding with coated electrodes is supplemented by complete descriptive data on all brands of electrodes manufactured by Metal & Thermit Corp. in a revised edition of their catalog. Bulletin Jy-64.

Alloys Steels
Why alloy steels are best for heavy equipment and other exacting applications is discussed in a folder by Bliss and Laughlin, Inc. A partial list of the more common grades gives machine ratings and turning speeds. Bulletin Jy-42.

Locomotive Steels
A comprehensive review covers specific applications, based on current practice, of various types of vanadium steels for locomotive and car construction. It contains 72 pages and is available to railway executives and engineers. Published by Vanadium Corp. of America. Bulletin Dy-27.

Firebrick
Babcock & Wilcox make an insulating firebrick which is refractory as well as insulating and can be used without a facing of firebrick. Description, applications, and engineering data are contained in Bulletin Fy-75.

Temperature Control
Costly overheating of furnace roofs can be prevented by the temperature-limit control described by Leeds & Northrup. Large dial, easy installation, and ruggedness are the features emphasized. Bulletin Dc-46.

Alcoa Notes
"Alcoa Random Notes" is the intriguing title of a little monthly paper got out by Aluminum Co. of America. A request for this bulletin will bring you a copy of the latest issue. Bulletin Ca-54.

Stainless Steel Facts
Carpenter Steel Co. offers (to manufacturers in U.S.A. only) a booklet, designed in handy file folder form, presenting a wealth of data on Carpenter stainless steels. A good reference source of material. Bulletin De-12.

Gold and Silver Plate
Important information about efficient and economical methods of gold and silver plating with precious metal cyanides is contained in a comprehensive booklet by E. I. du Pont de Nemours & Co. Specific data on equipment and operation are given. Bulletin My-29.

Model "Y"
The Sentry Model "Y" electric furnace, using the Sentry Diamond Block method of heat treatment provides exceptional quality high speed steel hardening at minimum production cost. The furnace is described in Bulletin Oy-114.

Metals for Corrosion
Fourteen varieties of Midvaloy corrosion and heat resisting metals are described in a detailed bulletin by The Midvale Co. Properties and applications are listed and illustrated. Bulletin Ca-160.

Mesh Products
Wire mesh is a class of material about which little is heard. A folder by C. O. Jelliff, therefore, telling the special alloys and metals used, styles of weaves and applications, is of unique interest. Bulletin Da-78.

Electric Salt Baths
Literature is available from Bellis Heat Treating Co. describing electrically heated bath furnaces which are economical to operate and have a wide range of applications in hardening, annealing, and heat treatment of high speed steel, stainless steel, nickel, aluminum, copper and bronze, etc. Bulletin Ny-48.

Moly Matrix
Climax Molybdenum Co.'s little monthly newspaper contains many interesting and informative articles. Get the latest issue—Bulletin Ax-4.

X-Ray Examination
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Abrasive Cleaning
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Electric Tempering
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Hot Work Steel
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A new development in plastic refractory lagging for temperatures up to 2200° F. is described in a bulletin by the Quigley Co. Properties, uses, and instructions for applying are included. Bulletin Fa-139.

Spectrometry
A chapter on basic theory and design of spectrometers or spectrographs explaining the principle of operation in full detail precedes a catalog of spectrometric equipment by Bausch & Lomb Optical Co. Bulletin Fa-35.

Thermometers
A complete catalog and price list with excellent illustrations covers all manner of thermometers and hydrometers, made by C. J. Tagliabue Mfg. Co. Bulletin Fa-62.

Grinding Carbide
A handbook has been prepared by Norton Co. to assist toolroom operators in selecting the proper grinding wheels for use on cemented carbides, which require entirely different tools and technique from high speed steel and stellite. Bulletin Fa-88.

Stainless Uses
Excellent illustrations and interesting text tell of the wide variety of applications of chromium stainless steels in practically every industrial field. Electro Metallurgical Co. Bulletin Fa-16.

Rolling Temperatures
Particularly applicable to rolling mill temperature measurement is Bristol Company's "Electronic Instagraph" by means of which temperatures can be measured while the steel is in motion. Bulletin Fa-87.

Bolts and Nuts
The calorizing process of driving aluminum into the surface of steel and the physical properties of bolts and nuts made from calite alloys are described in a folder by the Calorizing Co. Bulletin Fa-26.

Beryllium Copper
A reference work of new and up-to-date information on the unusual characteristics of beryllium copper contains helpful data on production, fabrication and heat treatment. Riverside Metal Co. Bulletin Fa-156.

Hy-Speed Case
A striking and interesting new booklet on Hy-Speed Case has just been published by the A. F. Holden Co. Typical applications and results are cited. Bulletin Fa-55.

Drawing Furnace
A new convected air gas fired furnace for drawing and tempering dense loads has been announced by Despatch Oven Co. Complete details concerning its design and operation, the results obtainable, and prices are given in Bulletin Dy-123.

Dust Collector
How the Schneible multi-wash dust and fume collector operates and what it does are clearly shown in a catalog giving details on existing installations. Published by Claude B. Schneible Co. Bulletin Ca-161.

Tool Room Furnace
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Cutting Oils
The problems of machine tool lubrication engendered by the high speed production and close tolerances of modern industrial operations are discussed and progress in cutting oils during the past few years reviewed in a booklet by D. A. Stuart & Co. Bulletin Jy-118.

Rustproofing
How the Detrex method of solvent degreasing provides the advantages of speed, economy, and satisfactory cleaning before all kinds of rustproofing and finishing operations is pointed out in a leaflet by Detroit Rex Products Co. Bulletin Dy-111.

Metal Heating
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Alloy No. 10
A high temperature muffle furnace, the first of the Hevi Duty line of laboratory furnaces equipped with Alloy No. 10 allowing working temperatures to 2400° F. Bulletin Jb-44.

Flux
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Furnace Control
How the Lindberg Control functions in balancing the rate of heating of a furnace or oven with the varying heat requirements is told in an attractive new bulletin issued by Lindberg Engineering Co. Bulletin Nv-66.

Air Weight Control
An illustrated booklet of sure-fire interest to the foundry trade has been issued by the Foxboro Co., explaining in detail the advantages of the "air-weight controller" used in America's leading foundries. Bulletin Ea-21.

Oxidation
Designers confronted with oxidation problems connected with cracking coils, polymerization plants, superheaters, high pressure steam plants, air heating equipment and recuperators will welcome a folder by Timken Roller Bearing Co. containing data on oxidation at 1000, 1250 and 1500° F. Bulletin Ea-71.

Calculator
A handy gadget is a sliding weight calculator which can compute weights per lineal inch of steel for 161,200 cross-sections. Pocket-size, it contains tables for rounds, hexagons, octagons, squares and flats. Distributed by Heppenstall Co. Bulletin Ea-122.

Sheet Metal
One of the most modern of the current pieces of industrial literature dealing with sheet metal is Republic Steel Corp.'s "The Path to Sheet Metal Permanence," a 20-page illustrated booklet. Bulletin Ea-8.

Rails
"Brunorizing" is a new method of producing an improved steel rail for today's heavier and faster trains. A nicely printed and well-illustrated 24-page booklet by United States Steel Corp. explains the process. Bulletin Ea-79.

Diamond Wheels
A striking presentation is made by the Carborundum Co. in a 52-page booklet on diamond wheels. Detailed technical information is contained and a price list attached. Bulletin Ca-57.

Sheet Containers
The mechanical and thermal requirements peculiar to sheet carburizing boxes are explained in an illustrated folder by Driver-Harris Co. describing this particular type of equipment in detail. Bulletin Ea-19.

Graphitic Corrosion
The peculiar form of disintegration occurring in cast iron which is known as graphitic corrosion is explained in a reprint of a technical article by Wesley, Copson and LaQue of International Nickel Co. Bulletin Ea-45.

Testing Machines
An extremely handsome, spiral-bound, segregated catalog tells all about the various hydraulic and screw power testing machines made by Tinius Olsen Testing Machine Co. Bulletin Oy-147.

Salt Bath
"Heating from the inside out" is what makes the Ajax-Hultgren salt bath furnace practical. Ajax Electric Co. explains this new operating principle in an interesting folder. Bulletin Oy-43.

Copper Bulletin
A new clearing house for news of developments in brass, bronze and copper, the "Copper Alloy Bulletin," issued by the Bridgeport Brass Co., made its appearance with the March issue. It is edited for the technical and engineering audience. Bulletin Da-163.

Toolmakers' Microscope
Only recently have optical methods of measuring and testing been introduced in the workshop. These methods — particularly adapted to measuring small and intricate parts — and the equipment used are fully described in a booklet by E. Leitz, Inc. Bulletin Da-47.

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Meehanite
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Hydraulic Tester
Of interest to all engineers recommending or purchasing universal testing machines is a book by Riehle Division of American Machine and Metals, Inc., on the development of the precision hydraulic testing machine. Bulletin Ba-157.

Alloy Castings
Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

Stainless Data Book
All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc. giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Liquitol
The use of Liquitol for controlled cooling of iron and steel castings and ingots is fully described in a bulletin by Alpha-Lux Co., Inc. Bulletin Ma-120.

Stress-Strain Recorder
The many applications of the Baldwin-Southwark stress-strain recorder, its unique advantages, and the many ways it can give unusual service will be extremely interesting to all who have to do with testing methods and equipment. Bulletin Ba-67.

Laboratory Service
A new edition of "The Metal Analyst" tells about an organization established by Adolph I. Buehler specializing in the installation of metallurgical laboratories. The complete line of laboratory equipment marketed by Buehler is also catalogued. Bulletin Dy-135.

Newer Tool Steels
Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

Port Valves
Diagrams and descriptive matter show the operation of adjustable port valves made by North American Mfg. Co. that are particularly suitable for mediums whose rate of flow is not constant. Bulletin Oy-138.

Photo-Electric Cells
If you are not familiar with the wide field of applications for photo-electric cells and apparatus, send for this very interesting and complete booklet by Pfaltz & Bauer, Inc., covering the original apparatus developed by Dr. Bruno Lange. Bulletin Ca-142.

Resistance Wire
A complete catalog of the various types of electric resistance wires made by the Hoskins Mfg. Co. has been issued. Complete numerical data are included on all types, along with some fundamental facts about heating units. A handy, small size 48-page booklet. Bulletin Jy-24.

Centrifugal Castings
Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

Cleaning Rooms
A catalog of designs for blast cleaning rooms incorporating many labor and time saving improvements making the blast room an unequalled mechanical device for low cost cleaning is published by Pangborn Corporation. Bulletin Ca-68.

Ni-Cr Castings
Compositions, properties, and uses of the high nickel-chromium castings made by The Electro Alloys Co. for heat, corrosion and abrasion resistance are concisely stated in a handy illustrated booklet. Bulletin Fx-32.

Rockwell Tester
A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

Hold-Heet Pyrometers
Technical information on pyrometer operations accompanies a full description and price list for Hold-Heet wall type and lance type pyrometers in a bulletin by Russell Electric Co. Bulletin R-164.

Chip Wringers
An attractive folder describes a machine for reclaiming cutting oil from chips or turnings, which will effect big savings. Bulletin R-165.

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Behavior of Metals Under Repeated Loads

By E. A. Snader, Metallurgist
Westinghouse Electric & Mfg. Co.
Philadelphia

This is the Second Lecture of the Philadelphia Chapter Course on "Metals—How They Behave in Service." The first lecture appeared in the May issue of THE REVIEW and subsequent issues will carry the others in this series of six.

In a consideration of the subject of fatigue it is well to point out the fallacy of the widespread conception of crystallization as the cause of failure of metals under repeated loads. In this lecture we will adopt the shorter word "fatigue" instead of using the long phrase "failure of metals under repeated load."

We all know that metals are made up of grains. I think Mr. Diederichs brought that out quite well in the first lecture of this series published in the June issue of THE REVIEW. These grains are composed of unit cells in which the atoms are arranged in some geometric pattern. Now when a metal fails through fatigue or repeated load, we know that there is no rearrangement of the atoms that go to make these unit cells, and therefore it is a self-evident fact that crystallization can play no part in the fatigue of metals.

It can be readily understood how engineers, before knowledge of the structure of metals became so widespread, on seeing the failure of a part that they knew had an initial elongation of, say, 25%, would ascribe that failure to some change in the structure of the metal itself, and say that the metal crystallized or changed its form. And it is also not surprising that a garage mechanic, seeing a crankshaft or an axle break off short that he knew he could tie into knots originally, would say that the metal crystallized. The habit of referring to fatigue as crystallization of metals has become very widespread among the lay public, and if I can do anything to dispel that idea, I will be well satisfied.

In order to present a true picture of fatigue, I am going to borrow an idea from a chess player. Capablanca, when chess champion, wrote a book called "Chess Fundamentals." He opened the book with a chapter entitled "Chess Endings." The middle section of the book he devoted to "The Middle Game," and the final chapter was "Chess Openings." This may seem to be putting the cart before the horse, but in a subject such as ours I think it is probably the best method of approach.

Nature of Fatigue Failures

First we will make sure just what a fatigue failure is. Figure 1 shows a fatigue failure of a large shaft in service. That particular piece of steel had an initial elongation of about 26%, tensile strength around 80,000 psi., and was in service a good many months before failure occurred. The failure started at the top of the photograph and progressed slowly, then more rapidly, gradually spreading about three-quarters of the way through the shaft. A similar crack started at the bottom and worked up until the remaining metal could no longer support the load and the end of the shaft broke off suddenly.

Figure 2 is an automobile axle taken from a car about four or five years old. This is the type of fatigue failure that the garage mechanic ascribes to a change in the crystalline structure of the metal itself.

Fig. 3—Fatigue Fracture in a Crane Hook (Chapman)

Figure 3 is a crane hook. This is a fatigue failure that you can get, yet fatigue failure progressed transversely starting at the little nick on the inside of the hook.

Figure 4 is a photo-elastic study of that same piece made up of celluloid. A nick was artificially produced, the same size as in the crane hook in Fig. 3, and the load applied. Lines of stress concentration appeared around the nick.

Fig. 1—Fatigue Failure of a Large Shaft

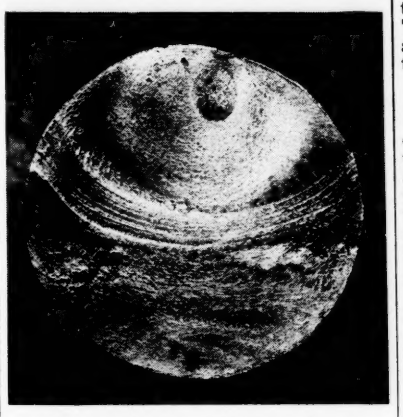


Fig. 2—Fatigue Failure of an Automobile Axle

The Fatigue Test

Our second consideration will be the fatigue test and the meaning of the "endurance limit."

The endurance limit is the limiting strength of materials under repeated stresses, just as the yield point, tensile strength, elastic limit, etc., are limiting values under certain static conditions. The endurance limit may be defined as the highest stress below which failure will not occur no matter how many times the application of this stress is repeated. The fatigue test itself, therefore, is merely the determination of the highest possible stress that a rotating or oscillating member will withstand, no matter how many times it is applied, without finally failing.

It is obvious that no test can be prolonged for an infinite length of time, but experiment has shown that if failure does not occur within 10,000,000 revolutions, cycles, reversals, or whatever you want to call them, the likelihood of failure is very remote at any number of reversals. About the only time that failure does occur after that period is when certain unusual conditions are present that will be considered later. This holds true only for ferrous metals. Non-ferrous metals vary considerably.

Now let us go back to Bill Diederichs' example of a piece of metal held in a vise. He showed that if you bend it to a certain angle and release it, provided it has not been stressed beyond its elastic limit, it will come back to its starting point. The same thing will happen if it is bent to the same angle in the opposite direction. Such a complete cycle is known as one reversal of stress. Mr. Diederichs also defined load, deflection and stress. Load is the external application of force. The result of that application of force is deflection. It may be so small that it can't be measured, but any application of load produces deflection. Stress is the reactive force—the internal resistance to the load in balancing the force.

Suppose we apply a load to this piece of metal in the vise, bending it back and forth and completing one oscillation. Then suppose we repeat this application of load a thousand times, and at the thousandth application it snaps off—a brittle fracture. If we reduce the angle of bend, we find that instead of bending it 1000 times we can bend it 10,000 times before fracture. Reduce the angle still more and 500,000 reversals are had before fracture. By this time our arm is starting to get sore so we hook on a fatigue testing machine. Finally we reach a point where no matter how many times we bend the piece of metal it does not fail. That is what is known as the endurance limit. It is the highest value at which the metal does not fail.

In the rotating cantilever type of fatigue testing machine the specimen is held with the shank end secured in the spindle collet, and a load is suspended from the free end by means of a ball bearing and weight holder assembly. The motor spins the specimen around; the top part is under tension and the bottom part is under compression all the time. As the specimen rotates, the stress alternates from tension to compression, just the same as the piece pulled back and forth in a vise. In other words it is an alternating bend test. An initial load is suspended from the specimen that is sufficiently high to cause failure after a comparatively few revolutions. The first point on the endurance curve is so located. Lesser loads are then applied to similar specimens until the point is reached where failure does not occur. A quicker way is to load up six or seven machines at the same time with similar specimens using different loads.

Plotting the Endurance Curve

Figure 5 on page 6 is a typical endurance curve. The plain points show where the specimens broke. The points carrying the arrows show specimens that did not break and the dashed line is termed the endurance limit.

These curves are plotted on a semi-logarithmic scale so that millions of cycles can be shown as clearly as a few thousand. The object of that type of scale is to compress into a short space points that would otherwise be impracticable to plot. For instance, if this curve were plotted on a standard scale, it would probably extend from here (Philadelphia) to Baltimore.

In plotting the curve for Fig. 5, the stress goes from zero to a maximum. The negative stress is neglected, but it should be remembered that it is a complete reversal. The stress range does not change provided the elastic limit of the material is not exceeded.

This rotating cantilever beam type of fatigue test gives alternating tension and compression stress at the surface. Another type is the simple beam test in which the specimen is supported at both ends and loaded in the center. The alternating torsion test is used to quite a large extent, and to a lesser degree the straight tension-compression test.

We will not go into a detailed discussion of fatigue testing here, but essentially all of the tests are the same. The object is to determine the maximum load that the material will withstand without failure. It is always preferable to use the type of test that the material will be subjected to in service.

Having first discussed the final fatigue failure then proceeding to the breaking of test specimens, we will now spend a little time on the cause of fatigue failures. Let us consider the start of a fatigue failure and find out just what causes a ductile metal to fail after months or years of service as though it had indeed been transformed into another material. The cause of the start of fatigue is controversial. There is considerable argument between atomic physicists and metallurgists as to just what occurs.

Cause of Fatigue Failure

One view, which has been very ably explained by Edwards, is that the crystals vary in their physical properties according to the orientation. If a crystal is located in such a manner that a weak point is in a region of maximum stress, a failure will start at that point and progress on through.

Remember how physical properties vary; the modulus of elasticity of a crystal of iron, for instance, may range from 19,000,000 to 42,000,000. In pure single crystal iron the tensile strength varies from 6000 to 22,000 psi. When we say that a bar of steel has a certain tensile strength, we mean that that tensile strength is the average of the aggregate and not the properties of the individual crystal. The figure depends on whether the load is applied normal to the slip plane or tangential to it.

In a specimen that is made up of crystals, there certainly will be some crystal that is unfavorably oriented; that is, its planes and directions of least strength lie in the line of greatest stress, and the crystal will start to crack in that direction. Once the crack starts, a concentration of stress forms around that point, and the crack will go straight through the piece.

That is an extremely logical viewpoint, yet nevertheless the work of Gough, who represents the other school of thought, is very hard to dispute. Gough's work on single crystals, described in *Proceedings*, American Society for Testing Materials, Vol. 33, page 3 (1933), shows rather definitely that fatigue is the result of slip. Slip, as so well described in Mr. Diederichs' first lecture, is merely the sliding of one plane of atoms over another, and since the effect of slip is to increase hardness, and since slip produced by cold working raises the endurance limit of the material, the question might well be asked, "How does slip cause fatigue failure?"

The answer is merely this: As long as slip has not ruptured the atomic bonds, the material is work-hardened or strengthened and the endurance limit

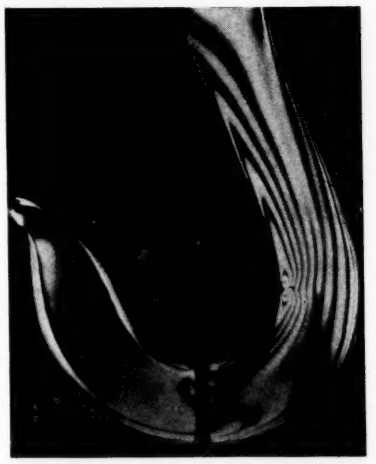


Fig. 4—Photo-elastic Study Showing Lines of Stress Concentration Surrounding Nick Where Fatigue Fracture Started (Chapman)

Behavior of Metals Under Repeated Loads

is raised. But just as soon as an internal rupture of the atomic bonds occurs, a concentration of stress is caused at that point, and it will continue to grow until it becomes a visible crack, and finally spread until failure occurs.

Just what causes this rupture of the atomic bond is another matter that is somewhat open to discussion. However, it is pretty well conceded that as the lattice is rotated during deformation, one plane will slide over the other just a little bit farther until the imaginary

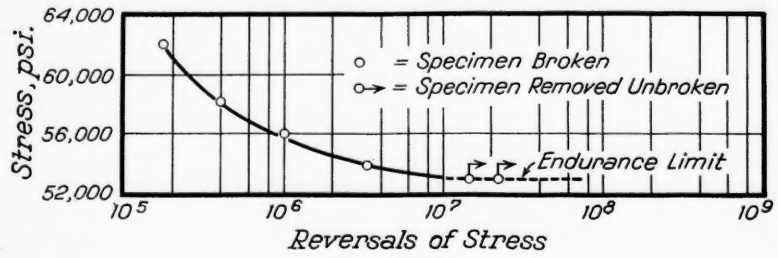


Fig. 5—Typical Endurance Curve

springs or bonds that hold these little atoms together finally break. Just as soon as that atomic bond is broken, it starts the incipient crack that eventually leads to the final failure.

We have referred a number of times to stress concentration or stress localization, and a few words on that subject might be in order.

Figure 6 shows the effect of a single notch and a continuous thread. The endurance limit of the normal material is 51,000 psi. This drops to 43,000 psi. when a ¼-in. threaded specimen with 28 threads to the inch is used. In the specimen with 28 threads per in. notch size for a single groove, the endurance limit is reduced to 12,000 psi. In a ⅜-in. 24-thread specimen the endurance limit is 21,000 psi. It does not drop quite as much, indicating that the sharper the groove the more pronounced the effect.

This matter of grooves and threads is merely an exaggerated exemplification of what occurs in the vicinity of any discontinuity in the crystalline body. Non-metallic inclusions, carbide particles, blowholes, etc., are all in effect "stress raisers," and all influence to some degree the resistance of metals to repeated loads.

Let us refer again to Fig. 4, which is a photo-elastic study of a crane hook showing stress concentration at the nick. Before we knew anything about photo-elasticity D. J. McAdam, Jr. showed by charts the effect of notches. Mr. Diederichs used an illustration in the first lecture of this course showing that when a force is applied to the end of the bar, that force is transmitted uniformly throughout the length of the bar. When that line of pull meets a notch or some discontinuity in the metal, it has to go around it. That was Dr. McAdam's original theory as to the notch effect on fatigue. These lines of pull build up what is known as lines of stress concentration. The photo-elastic studies show a few more curlicues, but essentially they are the same thing.

Corrosion Fatigue

A form of fatigue which we frequently hear about is corrosion fatigue. Here probably the two most deadly agents the metallurgist has to combat unite with disastrous results.

Like many notable discoveries, corrosion fatigue was stumbled upon quite by accident. McAdam at Annapolis was investigating the upper part of the fatigue curve, which, incidentally, was found to be above the tensile strength of the material. The investigation was interfered with by the self-annealing action of the specimen under the heavy load; that is, the internal friction created so much heat that the material annealed itself and failed at a very low point. This internal heat was generated by the greater and greater loads applied, the specimens occasionally becoming red hot. A stream of water was therefore played on the specimen to prevent this self-annealing and early failure, but the endurance limit was then found to have been greatly lowered. The conclusion was therefore reached that corrosion by the stream of water combined with cyclic stress was the cause of the low fatigue limit.

D. J. McAdam, Jr., in *Transactions*, American Society for Steel Treating, Vol. 11, page 355 (1927), published some figures showing the effect of corrosion fatigue. For instance,. a 5% nickel steel had a tensile strength of 132,000 psi. and an endurance limit of 66,000 psi. in air. Under a stream of fresh water the endurance limit was 19,000 psi. Even a 13% chromium stainless iron is reduced from a normal endurance limit of 59,000 psi. to 40,000 psi. in fresh water and to 13,000 psi. in salt water. These figures give some idea of the great damage that can be done by fatigue simultaneous with corrosion.

One feature of special interest in a consideration of corrosion fatigue is the complete loss of the beneficial effects of heat treatment and cold working. There is an intrinsic corrosion fatigue limit for each metal and corroding medium, so that no matter how a piece of steel is heat treated or cold rolled, the endurance limit under corrosion is the same, unless, of course, the heat treatment is such as to render the material more corrosion resistant, such as the heat treatments applied to alloys in the stainless group.

The question is frequently asked, "Does corrosion fatigue follow grain boundaries or is it trans-crystalline in nature?" The nature of corrosion fatigue is just the same as any other type of fatigue; it follows the line of slip within the crystal.

Another question frequently asked concerns the effect of grain boundaries. It has been known for some time that coarse-grained structures have a lower fatigue limit than fine-grained because of the fact that the larger the grain the larger the plane of slip. Thus the effect of grain boundaries is merely to inhibit slip.

The fatigue cracks generally cross right over the grain boundary without any tendency whatever to follow it. This, of course, excludes such complications as carbide precipitation where the grain boundaries are considerably more susceptible to corrosion than the parent metal, and the crack naturally follows the boundary.

This lecture merely skims over the elements of fatigue in an attempt to present a general picture of the subject without going too much into detail. We have endeavored to show that there is really little difference between the mechanics of static and fatigue failures; both are initiated by slip, and fatigue is the result of slip.

Discussion

Question: In heat treating we quite often decarburize the surface. I would like to ask Mr. Snader what the effect is on the fatigue limit of a piece of steel if the surface is slightly decarburized.

Answer: Decarburization is probably one of the most prevalent causes of fatigue failures. The effect is merely that when the surface is decarburized, that part of the material that is at the highest stress is weakened; that is, its strength is reduced to that of pure iron. When tensile strength is reduced from 80,000 psi. to 40,000 it is cut in half, and since endurance limit is approximately 50% of tensile strength, the endurance limit is reduced from 40,000 to 20,000 psi. A crack is therefore started at the surface that is only as deep as the decarburized metal. As a matter of fact, at the beginning it was just on the surface, but the concentration of stress occurs at that point. That stress may reach a value that is almost infinitely high, and it progresses very rapidly throughout the piece. The deeper the crack progresses, the higher the stress is built up. Thus the weakening effect of decarburization depends on the fact that the strength of the surface is lowered.

Question: May I ask Mr. Snader to go a little further and tell us about that case in reverse—as in nitriding, for instance?

Answer: We might take some approximate figures to answer that question. An un-nitrided steel might have an endurance limit of about 70,000 psi. This is raised by about 8000 to 12,000 psi. by nitriding. The reason for this is merely that the strength of the outer layer is increased, and by increasing the tensile strength of the outer layer the endurance limit is increased, preventing the start of the crack that would ultimately lead to failure.

Question: You referred to a fatigue crack starting from a nick in a crane hook. But a crane hook in service is bound to have a lot of little dents and cracks that take on the polished appearance which leads you to suspect they are beginning to be unsafe.

Answer: If you have to use that nicked hook, take a rounded file and blend the nick out. Where there is an angle there is bound to be considerable crowding at the point of that angle, and the lines of force or stress are going to come into contact. If you blend the angle out into a smooth curve, even if you have to go a little deeper, there will be a sweep of lines of force without a concentration of stress. Re-entrant angles or sharp changes should be eliminated.

Question: In a welded structure there is usually a difference in grain size between the weld metal and the metal adjacent to the weld. From your talk I gathered that there is a stress concentration where there is a variation in grain size. On such welded structures is this concentration of stresses going to cause a failure right along the edge of the weld, or is it going to occur in the weaker grain structure?

Answer: I don't think that there will necessarily be a stress concentration at the line of fusion. It depends largely on what is being welded and whether it is given a stress relieving treatment. If the welding is properly done so as to insure interpenetration or fusion, and it is given a stress relief treatment afterwards, then I can't see any reason why it should fail by stress concentration.

Question: I would like to ask if there is any indication as to fatigue resistance given by the tension test. Does a combination of certain physical characteristics such as ductility and strength indicate fatigue?

Answer: Endurance limit or fatigue strength is a function of the tensile strength of a given material, and also of the treatment. That is, it varies slightly with the treatment, and varies considerably with the material. In general it will run between 45% and 55% of the tensile strength. In some steels, such as the 5% nickel, low carbon steel, it will be as high as 60 or 62%.

But we do know that once we have determined that endurance *ratio*, it is a fixed value, and it is not necessary to run an endurance test every time the endurance limit of a particular steel is desired. That is why short-time fatigue tests seem to me so useless. No short-time test is really anything more than an approximation, and not as close an approximation as can be had from the tensile strength of the material.

Question: Does 45 to 55% of the tensile strength for fatigue value apply only to steel, or to other materials?

Answer: The ratio of 45 to 55% holds only for steel. On non-ferrous metals it is generally considerably lower and usually varies with the alloy. However, a relationship between tensile strength and fatigue value does exist.

Question: Since tensile strength can be approximated from the Brinell test (by multiplying the Brinell number by 500), wouldn't it be possible to determine fatigue limit by merely running a Brinell test?

Answer: Yes. Tensile strength governs endurance limit directly and Brinell hardness indirectly. It is, of course, only an approximation. In non-ferrous metals that ratio is lower.

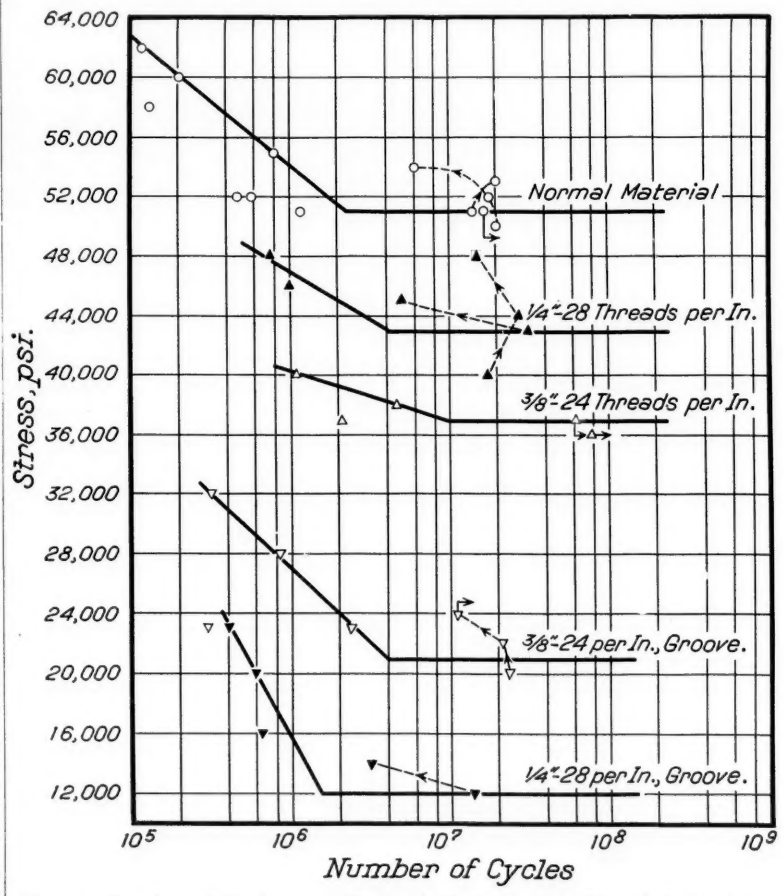


Fig. 6—Results of Endurance Tests of Grooved and Threaded Specimens (Moore)

The Junior Members' Own Page

This Thing Fatigue

By George L. Kehl
New Jersey Zinc Co. Fellow
Lehigh University

[First prize of $5.00 for the best answer to the question "What is fatigue of metals?" has been awarded to George L. Kehl, whose answer is printed here. J. Earle Harrington, chemical engineer, City of Chicago, has been awarded second prize of $3.00, and Fielding S. Ellis, Alan Wood Steel Co., Conshohocken, Pa., third prize of $2.00.]

During the past 20 years metallurgists and design engineers have been asking for more information and data on a mysterious thing thing called fatigue of metals.

Of course, in the strict sense of the word, a metal does not become fatigued. The human body, after a severe workout, becomes tired and fatigued, but after a short rest period it is as good as new and again functions normally. However, such is not the case with metals. If a metal is subjected to a workout by alternate or repeated stressing and then allowed to rest, any damage brought about by the repeated stressing would not be eliminated, regardless of how long we allowed the piece to rest.

Not so many years ago, the sudden failure of train car axles, airplaine propellers, connecting rods, and other moving machine parts was laid to a great number of causes, with no little emphasis placed on the "crystallization" of the metal. This erroneous conclusion was drawn from the appearance of the fracture. A portion of the fracture invariably appeared fine and silky and the remainder coarse or "crystalline," with a sharp line of demarcation between the two portions.

We know today, however, that fatigue failure is usually started on the surface of the metal. When a metal is subjected to alternate stressing at a stress of sufficient magnitude eventually to cause failure, even though the applied stress would statically have no ill effects, small submicroscopic cracks are formed on the surface. Surface imperfections such as minute inclusions, scratches, pits, and sharp-cornered fillets serve as nuclei for these cracks. As the repeated stressing is continued, these small cracks develop in size and number and are gradually propagated to within the interior of the piece.

Eventually the cross-section of the piece is so weakened by lack of supporting metal that it fails abruptly, with no warning whatsoever. We again have the typical looking fatigue fracture. The silky portion is the result of the two co-surfaces rubbing together — the coarse or "crystalline" portion is caused by the quick break, no time being allowed for these particular surfaces to be in rubbing contact with each other.

The question may well be asked, "How can we prevent fatigue failure in members subjected to vibration?" A general answer is: Beware of surface imperfections; eliminate sharp-cornered fillets and sharp changes of cross-section; have the material thoroughly homogeneous throughout; and watch design.

Permanent and Summer Jobs Taken by Rolla Men

All members of the Missouri School of Mines Group of the American Society for Metals have left Rolla for work in their profession.

Permanent positions have been taken by five members as follows:

Charles F. Benner, General Electric Co., Pittsfield, Mass.

S. S. Post, General Electric Co., Bridgeport, Conn.

J. J. Beinlich and J. W. Frame, Carnegie-Illinois Steel Corp., Pittsburgh.

W. W. Culbertson, American Steel and Wire Co., Cleveland.

The others, who have summer positions, are as follows:

B. J. Lewin, Lewin Metal Co., East St. Louis, Ill.

Henry Steinmetz, Eagle-Picher Lead Co., Galena, Kan.

Joe Howerton and N. L. Peukert, South Works, Carnegie-Illinois Steel Corp., Chicago.

Charles Lee Clayton, M. E. Nickel, T. J. Finley, and R. C. Tittel, Wisconsin Steel Works, South Chicago.

C. K. Tharp, Texas Electric Steel Casting Co., Houston, Tex.

Carnegie Tech Establishes New Research Fellowship

A research fellowship to run three years and pay $1200 annually has been established in the Department of Metallurgy at the Carnegie Institute of Technology by The International Nickel Co., Inc., of New York City.

Richard T. Myer, a graduate student at Purdue University, has been selected to receive the fellowship. The research project, which is yet to be decided, will be studied under the direction of Dr. R. F. Mehl, head of the Department of Metallurgy.

Carnegie Tech's Department of Metallurgy now has available ten assistantships and fellowships for graduate students, six of which are supported by industrial concerns, including the Aluminum Co. of America and the Molybdenum Corp. of America.

Bob Gets Final Metallurgy Lesson Explaining Martensite and Austenite

"Now, Bob, the samples we're going to look at this week really look like something."

"Hm, none of them look like much of anything to me."

"Sorbite and troostite are rather nondescript, I guess, and they are hard to identify. But once you see martensite and austenite, you're pretty sure to know them again the next time."

"Sort of a speaking acquaintance. eh Al?"

"Yes. Well, here you are. Squint into this microscope and tell me what you see."

"Whew! That really is quite a pattern. Which one is this?"

"This is martensite, and that needle-like structure is characteristic of it."

"But now, is this the same kind of steel you showed me last week when we looked at sorbite and troostite?"

"Yes, this is a carbon steel of the same general composition, but it was cooled more rapidly."

"You mean that just by cooling it faster you can change the appearance that much?"

"Yes, dumbbell, that's what we've been talking about ever since you first looked at a photomike of pearlite."

"I know, but this one must be something entirely different. Sorbite and troostite, you told me, contained cementite and ferrite just like pearlite, but in a more finely divided condition. This surely can't be the same thing again."

"You're forgetting something, Bob. Sorbite and troostite contain another constituent too, you know."

"That's right. Don't tell me. Let's see—you called it a solid solution of cementite in ferrite, or alpha iron, didn't you?"

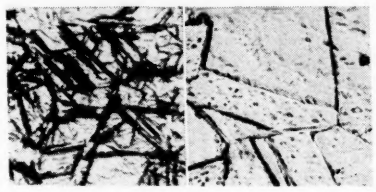
"Exactly. And troostite contained more of that constituent than sorbite, remember?"

"Yes, and I suppose since troostite was cooled faster than sorbite, and martensite is cooled faster than troostite, that martensite has still more of it."

"Marvelous deduction, my boy, marvelous. Martensite is essentially a solid solution of cementite in alpha iron — at least as far as the brass hats can agree. The nature of martensite is still very much of a controversial subject."

"So is alpha iron — as far as I'm concerned anyway. You haven't explained that to me yet, you know."

"Hold your horses. We're getting to that right now. I don't know whether you learned anything about allotropy in chemistry, did you?"



Martensite *Austenite*

"Seems to me I have a vague recollection of hearing the word."

"Well, certain elements such as iron are able to exist in different forms having a different crystal structure and slightly different properties."

"I remember now. Carbon in the form of the diamond and of lamp-black is the classical example."

"That's right. Now the form in which iron ordinarily exists at room temperature is known as alpha iron. Ferrite is alpha iron. But at a temperature above 900° C. the crystal structure changes and we have what is known as gamma iron."

"Nine hundred degrees is a pretty high temperature. I shouldn't think you'd have to worry much about it."

"For some purposes though it's an advantage to keep that structure at room temperature, and it can be done. But here, Bob, take a look at this last sample."

"Austenite, I take it."

"Right."

"If ferrite is alpha iron, I suppose austenite is gamma iron."

"Pretty close, Bob. Austenite is a solid solution of carbon or cementite in gamma iron."

"But how do you get it in this cold piece of steel if gamma iron changes to alpha at 900° C.?"

"With extremely fast cooling the transformation can be retarded and some austenite retained at room temperature, but this is rare and usually it is necessary to add alloys to the steel in order to retain the austenite."

"And if you cool it not quite so fast, you get martensite, is that it?"

"Right. The gamma iron changes to alpha. That is, the austenite decomposes during the cooling of a piece of steel to form martensite, troostite, sorbite, or pearlite, depending on the rate of cooling."

"Well, Al, I guess you ought to be a professor. Much as I hate to admit it, you did a good job explaining this stuff to me. It was mighty interesting."

Contact Metallurgy Forms New Field

Two Other Fields for Graduate Engineer Are Research and Production Metallurgy

By Richard W. Simon
Metallurgical Assistant, Pittsburgh District
Carnegie-Illinois Steel Corp.

[This is the second portion of an address delivered by Mr. Simon before the senior metallurgists at Carnegie Institute of Technology. The first part of the talk, which discussed the fields of research metallurgy and production metallurgy, appeared in the May issue. THE REVIEW sincerely regrets that the author's name and source of the article were inadvertently omitted at that time.]

The third general field in which metallurgists may follow their career is the work of giving to their company's customers a desired or needed technical service. This field is comparatively new, but even today it has assumed major importance in many metal producing or working industries.

The contact metallurgist is well known, but is acclaimed only when he can prove he is of definite service to all parties involved in his contact. He is the intermediary between his company's operating, sales, and management personnel and that of his customer's purchasing and operating departments.

First of all, this technical service expert must have most of the qualifications required of a first class salesman. People must like and respect him and by people we mean customer's executive and operating personnel from the president or purchasing agent down to the foreman of a certain processing operation. In fact, his work is often successful only when a skilled laborer on a troublesome job is willing to give him full cooperation.

That is only a part of his contact for the management and operators of his own company must so depend upon him that they will take his advice freely and welcome his suggestions even though occasional hardships are encountered in so doing.

The customer and his own associates must have full confidence in his ability, and as a consequence this ability must be built upon a solid training and wide practical experience. A technical education in metallurgy is necessary, but more important is a full familiarity with operating problems both as affecting the sequence of operations at his own plant and the widely varied processing which his customer may put upon that product.

He must be closely in touch with the production metallurgist and at the same time be able to understand the research metallurgist's viewpoint.

Deciding the Future

Broadly speaking, the graduating metallurgist will eventually find himself in one of these three fields of work. He certainly owes it to himself and to his employer to make sure he is not a contact metallurgist doing research work, or vice versa.

It seems evident that no one man can qualify for optimum service in all three fields. A careful self analysis followed by general metallurgical experience in an operating plant should enable him to decide how his future course is to be charted.

Above all, the young graduate should remember that his twenties are probably the most impatient years of his life. Let him continually study and analyze himself so as to readjust his plans rather than become discouraged.

Steels of U.S. Are Equal to Europe's Best

Kinzel Reviews Factors Affecting Development in European Steel Manufacture

By Merrill A. Scheil

Milwaukee Chapter — A delightful discussion of "Factors Affecting Developments in European Steel Making" was given by A. B. Kinzel, chief metallurgist, Union Carbide and Carbon Research Laboratories, Inc., at the meeting on April 23.

In France and Germany 50-ton open-hearth furnaces are rare and 25 to 35 tons are the standard. The crucible process is much in vogue for fine steels and can compete because of the cheapness of labor. Ingots are bottom poured centrally from a mother ingot and average 3 to 5 in. in diameter.

England is undergoing a revival of the steel industry, especially in equipment, such as arc furnaces and continuous strip mills.

France, because of high tariff duties, manufactures practically all of her ferro-alloys.

Germany cannot import nickel so must revise long-standing analyses. This has resulted in new alloy steels such as the Cr-Mn-Cu type known as *Baustahl* and *Union Stahl*. Substitutes for the 18-8 chromium-nickel stainless steel are 18% Cr, 6% Mn, and a newer type with 18% Mn and 8% Cr.

Aluminum is used sparingly and grain size control is only practiced in England in two plants.

Silicon alloys are used in Germany for deoxidizers. A Si-Zr alloy is used for fine-grained steel and Ca-Si or Ca-Si-Mn alloys are used to give clean steel without fine grain.

The European contention is that their clean steels, coarse grained, are better from a standpoint of service. They contend, from tests of special drill steels and upsetting die steels, that larger-grained steels are advantageous and are the equal of any of our fine-grained steels.

Sweden, because of high grade ores, produces stainless steels that are the equal of any of the standard U.S. grades. In general, American quality steels are equal to the best in Europe.

Dr. Kinzel described the steel works he visited in Russia, and told of the remarkable progress they are making. The research and testing facilities are of the highest order in many of these plants.

Spade Speaks on Stress Analysis at Golden Gate

By C. W. Horack

Golden Gate Chapter—After announcement of the new officers for the coming year at the May meeting, the technical talk of the evening was presented by James H. Spade, who is connected with the Ludlum Steel Co. at Los Angeles. Mr. Spade spoke on photo-elastic stress analysis.

He first gave a brief summary of the origin and use of polarized light and then discussed the stress patterns that were projected upon the screen from a variety of test models. The models used showed the effects of sharp corners, fillets, variable sections, including those simulating various kinds of welds.

Golden Gate appreciated greatly having Mr. Spade come from the neighboring chapter to give so much enlightenment on this timely subject.

G. E. Executive Engineer Defines Object of Research

Chicago Chapter—At the final meeting of the season on May 13, a bit of entertainment was provided by the Misses Carter and Williams, singing and dancing stars. This was a return engagement, in response to many requests, provided through the efforts of Paul Kurtz, chairman of the Entertainment Committee.

Following election of officers, Laurence A. Hawkins, executive engineer, Research Laboratories, General Electric Co., addressed the Chapter on the subject, "Research, What, Why and How."

A graduate of Williams and later of Massachusetts Institute of Technology, Mr. Hawkins entered the electrical field in 1899, with the Stanley Electric & Mfg. Co. In 1903 he joined General Electric at Schenectady as a patent attorney. He was transferred to the Research Laboratories in 1912, and in 1927 was appointed to the position which he now holds.

He acts as business manager and coordinator of the varied research activities of over 300 scientists in the General Electric organization.

The speaker classified his subject as intensive or engineering research, wherein study is directed at a specific goal; and as extensive or fundamental research, in which no goal is set, but new scientific facts are developed which may be employed in either intensive research or for furthering extensive research.

Mr. Hawkins discussed the subject in a most interesting manner, using specific illustrations drawn from his work and experience with the General Electric Laboratories.

Genial "Secretary Bill" Muses Didactically on the Status of the Cosmos

By H. D. Churchill

Cleveland Chapter—On May 3, the final meeting of the 1936-37 season was held at the Cleveland Club with President E. C. Bain and Secretary "Bill" Eisenman as honored guests.

After the dinner, genial "Secretary Bill," as coffee talker, gave a very profound and erudite dissertation on a subject close to the heart of every Society member—"Didactic Musings on the Status of the Cosmos." There is a rumor, probably without foundation, that when Bill was writing the title for his speech, he made a mistake and picked up a dictionary instead of the Handbook.

Following the installation of the officers for the coming year, the audience settled down to the serious business of the evening, namely, listening to Dr. Bain talk on "Some Apparent Anomalies in the Hardening of Steel."

Dr. Bain's address was intensely interesting and instructive. With clear-cut sentences, logical and purposeful thought, and numerous slides, he clearly brought out the changes that take place in the cooling of steel and showed why various constituents and rates of cooling affect the hardness, and what factors affect the hardenability of a steel.

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AMERICAN SOCIETY FOR METALS
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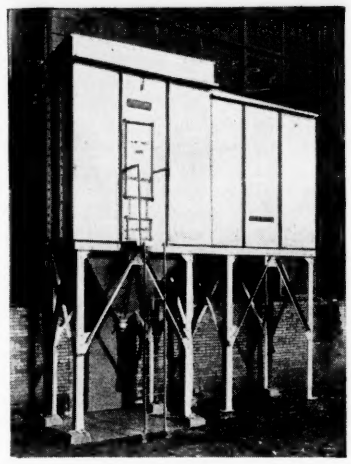
Dust Abatement in Foundry Operations

By C. A. Snyder
Dust Control Engineer
American Foundry Equipment Co.



Dust Control Device for Foundry Use

Good housekeeping and the prevention of silicosis are only two of the many reasons for dust control and abatement in the foundry.

Sandblast rooms should be supplied with sufficient mechanically forced draft to keep the dust created inside the enclosure, and carry it away from the operator fast enough to assure ample vision of the work.

In tumbling barrels a vent pipe velocity of 4000 to 5000 ft. per min. will generally supply a sufficient amount of air movement to keep atmospheric dust concentration below the danger point.

Effective hoods and proper ducts should be provided and properly maintained for grinding wheels.

Shakeouts, sand handling equipment, and other miscellaneous operations require special equipment to comply with existing conditions.

There are many types of dust collecting devices available, of which the cloth tube or bag collector is rapidly becoming the most popular. Its advantages are:

1. Absence of rigid screen frames allowing better cloth cleaning and eliminating cloth wear and corrosion.
2. More efficient cleaning mechanism.
3. Ample spacing of filtering units.
4. Ease and infrequency of maintenance and inspection.

Electrical precipitation is probably the most efficient of all collecting devices, but the high installation cost usually makes its use prohibitive.

Other types, each of which has advantages in particular applications, are the centrifugal collector by blowpipe contractor, the multiple cyclone, the wet collector, and the cloth screen arrester.

E. F. Davis Gives Peoria Thorough Account of Gears

By T. P. Black, Jr.

Peoria Chapter—The dinner talk on May 10 was entitled "Hobbies" by Paul F. Bourscheidt, a prominent Peorian and brother of Oscar Bourscheidt, newly elected Chapter chairman.

Four cash door attendance prizes were drawn amid considerable argument as to whether the lottery was "fixed."

Technical program for the evening was a talk on the metallurgy of modern gears, presented by E. F. Davis of the Warner Gear Co., Muncie, Ind. He gave a thorough account of construction, metallurgical properties of the steel used, and applications of the gears manufactured by his company.

Technical chairman was G. C. Riegel.

Cast Iron Talk Is Flash of Theory and Some Applications

Philadelphia Chapter—The last technical meeting of the season rolled around on April 30, leaving the field open for sectional meetings, golf tournaments, and plant visitations.

Speaker at this meeting was J. S. Vanick of the International Nickel Co. His very interesting subject was "Modern Cast Iron."

As Mr. Vanick expressed it, he gave us a flash of theory and then some applications.

Some of the anachronisms of the industry today were noted. Cast iron metallurgists are trying to keep impurities such as phosphorus and sulphur out of their product, while steel metallurgists are beginning to put them back.

Cast iron metallurgy has long been overshadowed by the rapid advances in steel manufacture and applications, but is now coming into its own. Development has been slow because cast iron is a more complex material than steel.

Progress has taken place in three principal directions. Strength and structure have been improved by modified methods of manufacture. The useful range has been enlarged by alloying. Heat treatment and its possibilities are being investigated.

Employment Service

Address answers care of A. S. M., 7016 Euclid Ave., Cleveland, unless otherwise stated

Positions Open

FOR DEVELOPMENT engineering sales, special metals, having wide application in manufacturing equipment, a copper and brass metallurgist thoroughly familiar with all phases production, heat treatment, etc. Full details first letter. Box 6-50.

STRAIGHTENER and heat treater, familiar with straightening all types of heat treated steel. Commercial steel treating plant located in Chicago. Advise experience and wages expected. Box 6-55.

TECHNICALLY EDUCATED man, age 29 to 32, who has had practical steel mill experience, preferably in the galvanizing, tinplating and pickling departments. Applicant should have flair for selling, as position to be filled calls for technical and practical sales service of heavy chemicals to the steel and allied industries. While salary will depend upon applicant and experience, it will not be less than $3000 per annum to start. Box 6-60.

DIE HEAT TREATER: Modern forge plant located in Seattle with up-to-date heat treating equipment. A steady job for a good man in a union shop paying union wages. Box 6-65.

Positions Wanted

METALLURGICAL sales or contact work in the steel industry. Graduate metallurgical engineer, University of Wisconsin, 1935. Experience in metallurgical laboratory and testing and all phases of production of both carbon and alloy steels. Box 6-5.

PRACTICAL HEAT TREATER with a thorough grounding in the basic fundamentals of metallurgy desires to make new connections having a future. Has completed two years of college work. Age 23. Practical experience obtained in commercial and industrial heat treating establishments. Milwaukee territory preferred but not essential. Box 6-10.

METALLURGIST: 8 years experience in electric furnace melting of alloy steels and metallurgical research. Technical graduate. Box 6-15.

COLLEGE GRADUATE: Between 25 and 30 years old; married; now employed. Has four years experience in heat treating, metallography, physical testing, and routine chemical analysis of steel. Desires a responsible position in the metallurgical department of a company that presents opportunity for advancement. Prefers Cleveland territory, but not essential. Box 6-20.

PROFESSOR OF METALLURGY desires to return to industry. Ph.D. in physical chemistry and physical metallurgy. Four years industrial experience. Six years experience teaching metallurgy in engineering schools. Details of training and experience with good references available. Box 6-25.

YOUNG MAN, 27, with metallurgical education desires change in employment. Prefers fairly large progressive company. Now employed by company doing heat treating and forging and making grey iron castings. Box 6-30.

METALLURGICAL and Chemical Engineer with 15 years experience in laboratory, heat treatment, production, sales, and management. At present employed as purchasing agent and desires to make a change. Box 6-35.